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Original article

A new framework for the sustainable development goals of Saudi Arabia

Ali AlArjani [a,1], Umar Muhammad Modibbo [b,c,2], Irfan Ali [b,3], Biswajit Sarkar [d,*,4]

[a] Departrment of Mechanical and Industrial Engineering, Prince Sattam Bin Abdulaziz University, Al-Kharj 16278, Saudi Arabia
[b] Department of Statistics & Operations Research, Aligarh Muslim University, Aligarh 202002, India
[c] Department of Statistics & Operations Research, Modibbo Adama University of Technology, P.M.B 2076, Yola, Nigeria
[d] Department of Industrial Engineering, Yonsei University, 50 Yonsei-ro, Sinchon-dong, Seodaemun-gu, Seoul 03722, South Korea

ABSTRACT

Achieving sustainable development goals agenda 2030 is the aspiration of all the United Nation's member countries. Countries have an uneven distribution of natural resources, economic strength, and capacity building. Many studies analyze these goals using various models and considering different aspects of the kingdom of Saudi Arabia's (KSA) economy. However, none of the studies modelled the key indicators mathematically to quantify the achievement level towards vision 2030; hence aims to bridge the existing literature gap In this paper, the sustainable development goals (SDGs) of KSA are considered, a mathematical model is formulated in light of fuzzy and weighted goal programming using membership function. The model comprises three goals related to the gross domestic product, sustainable energy consumption and employment capacity of the economy's contributing sectors. The analytic hierarchy process integrated to compute the goals' weights using row geometric mean method. The study established the goals's satisfaction level with 57% overall achievement of the vision 2030. Individually, economic growth goal is 45% achievable. The clean energy consumption-related goal is 67% realizable. The employment-related goal is 78% attainable within the time frame of the vision 2030. The study suggests that KSA diversify its energy sector by concentrating and investing more resources in alternative energy sources, including renewable energy such as solar, wind, biomass, and nuclear energy. Also, there is a need to involve more vibrant and talented youths in the critical decision-making process. The model is simple and can be replicable in a similar country with slight modifications.

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1. Introduction

Saudi Arabia is among the top twenty in the world economically, and it comprises of fourteen regions with a population of over thirty-four million people (GAStat, 2019). The regions include Al-Riyadh; Makkah Al-Mokarramah; Al-Madinah AlMonawarah; Al-Qaseem; Eastern region; Aseer region; Tabouk region; Ha'il region; Northern Borders; Jazan region; Najran region; Al-Baha region; and Al-Jouf region. Historically, its economy's progress heavenly relies on oil's high revenues. The revenues decreased during low oil prices globally due to any economic meltdown, outbreak, or pandemic diseases such as COVID-19, among others. This problem can be augmented through energy diversification by investment in renewable energy sources (RES) and nuclear. The country has the largest crude oil production capacity- about 12 million barrels per day, and holding the world's 16 per cent proved oil reserves ranking second after Venezuela (EIA, 2017).

The country's gross domestic product (GDP) is 769,681 million Saudi Arabian Riyal (SAR). The GDP per capita is 22,292 SAR, with gross savings to GDP of 3.1 per cent during the last quarter of 2019 (SAMA, 2020). The KSA economy depends highly on energy consumption, leading to high carbon emissions. Ensuring a greener environment requires technological innovation to reduce greenhouse gases (GHGs) such as CO_2, CH_4, $and N_2O$. Saudi Arabia has many programs under the auspices of vision 2030 in realizing the sustainable development goals (SDGs) set by the United

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Nations (UN). Therefore, it will be interesting for the decision-makers to know how much the SDGs target achievable at the end of the year 2030. Hence, this motivated the research work.

The remaining paper is organized as follows: Section 2 reviews the literature and established the research gap. Section 3 review the socio-economic study of KSA. In Section 4, the sustainable development goals are presented. In Section 5, the SDGs model formulation are discussed, while Section 6 presents and discusses the solution methodologies. 7 analyzes and discusses the results. Section 8 concludes the study.

2. Literature review and research gap

Over the years, research has been ongoing in the field of economic sustainability and development of the KSA. The effect of agricultural share and energy consumptions on the emissions of CO_2 per capita for KSA had been analyzed (Mahmood et al., 2019). The efficiency of energy consumption and their economic, cultural, technical, and institutional barriers for KSA had been studied (Alyousef and Abu-Ebid, 2012). The study analyzed scenarios and recommended policies and regulations for optimal energy mix and efficient supply to meet customer demand. A structural time series analysis was conducted for forty-two years from 1971 to 2013 in assessing the environmental quality of KSA relating to the total consumption of oil and carbon emission in the transportation sector of the economy (Alkhathlan and Javid, 2015).

Current energy conservation programs were highlighted, and significant policies and strategies to the achievement were proposed (Al-Ajlan et al., 2006). The effects of its growth are estimated; decomposition methods were then used to analyze the exogenous factors in mitigating such growth (Alarenan et al., 2020). In KSA, the power sector was examined in the direction of future attaintment for load balance target and control of consumptions (Al and Csala, 2019). They established the relationship amongst the consumption, peak load, and generation capacity in the long-run electricity demand growth.

The multivariate approach was used in investigating the causal relationships amongst energy consumption, price, carbon emissions, and economic growth in KSA (Alshehry and Belloumi, 2015). The GDP growth under vision 2030 of the KSA was estimated by multiple regression and principal component analysis using knowledge-based rather than the oil-based economy (Amirat and Zaidi, 2019). The sustainability and RES for the KSA have been intensively reviewed according to its vision in 2030 and documented (Amran et al., 2020). The research found that solar energy has potentials technological advancement in generating electricity to satisfy the KSA teaming population's future demand. Similar research regarding economic growth, carbon emissions, and energy efficiency in KSA are found in (Howarth et al., 2017; Rahman et al., 2017).

Many authors study mathematical modelling approaches for the SDGs agendas 2030 regarding different countries in the literature. Sarkar and Sarkar (2020) and Habib et al. (2020) discussed about sustainable production systems and biodiesel, respectively. Some of them used goal programming (GP) with satisfaction (Ali et al., 2021; Nechi et al., 2019). Others integrated fuzzy goal programming (FGP), weighted GP (Nomani et al., 2017; Jayaraman et al., 2017), while others employed fuzzy logic, simulation models, multi-criteria approaches, interactive structural modelling (Jayaraman et al., 2015).

2.1. Research gap

Over the years, research on the economic growth and development of KSA had been ongoing. Recently, energy efficiency and its

associated challenges have been studied and documented (Mezghani and Haddad, 2017; Alarenan et al., 2020). Most of the research carried out considered either energy efficiency or carbon emission of the country and did not quantify whether the SDGs agendas 2030 will be achieved or not as well as the achievement level. However, this research proposes a nobel concept of mathematical modelling incorporating multi-objective optimization to investigate KSA vision 2030 SDGs' attainment. The concept and the results obtained are different from the existing literature.

3. An Overview on Employment, Energy, GHGs and GDP

This section briefly describes some economic sectors of KSA like employment, energy efficiency, GDP, GHGs emissions, and electricity consumption.

3.1. Employment

The total economic dependency ratio of KSA is 125 per 100 people. Table 1 indicates that 64.82% male citizens of the age group fifteen and above engaged in the labour market. Simultaneously, their female counterpart has only 35.18% engaged in services, given the total number of employment to 3,170,272 during the last quarter of 2019. The percentage of males' participation rate in the labour force is 66.6 while the female is 26, with an employment rate of 95.1 and 69.2 percent for both males and females. Alternatively, 945,387 of the same age group seek jobs in the kingdom, given rise to an unemployment rate of 2.2 percent for males and 21.3 percent for females. Riyadh has the highest employment rate, followed by Makkah and Eastern province with 40, 20, and 18 percent. In contrast, Al-Jouf has the highest unemployment rate, followed by Al-Baha and Jazan with 14.8 12.5 and 10.5 percent, respectively. The regional total employment distribution of KSA by gender and unemployment rate are presented in Table 1 and pictorially in Fig. 1a. The country's total employment is 94.3 percent, and the unemployment rate is 5.7 percent during the fourth quarter of 2019. The employed persons work on average for 42.9 h, with monthly total average wages of 10,256 SAR (GAStat, 2019).

3.2. Energy efficiency and electricity consumption

The KSA has more than 100 major oil, gas fields, and 1,500 oil wells (Alyousef and Abu-Ebid, 2012). The country is experiencing high energy consumption per capita of 8,954.06 kilowatts per hour (KWh) with yearly consumption of 299,188 gigawatts per hour (GWh) during the year 2018 (ECRA, 2019). The consumption is categorized into four major sectors as residential (44%), commercial (16%), government (15%), and industrial (19%). The respective consumption amount is seen in Table 2 and pictorially represented in Fig. 1b. The high consumption could be due to low oil price (around SAR 1.88 per gallon), hot and arid climate around $(45 - 54)°C$, and lack of public awareness. Majorly, residential (cooling and domestic use), industrial sector, and desalination consume more energy. Because of hot weather, especially from April to October every year, more than seventy percent of electricity is consumed by cooling systems during this period (Mahmood et al., 2020).

3.3. Gross domestic products

The economic contribution of every sector in a given nation is known as the GDP per capita. It is measured as a ratio of the sectors' GDP output (expressed in millions euro in 2015) by the total employees in that sector (expressed in thousands) during the com-
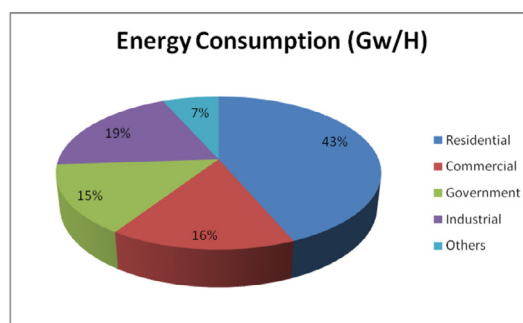
Table 1
Regional total employment by gender and unemployment rate.

S. No.	Regions	Males (%)	Females (%)	Total (%)	Unemployment rate (%)
1.	Al-Riyadh	25.87	14.35	40.22	4.9
2	Makkah Al-Mokarramah	12.24	7.28	19.52	5.1
3	Al-Madinah Al-Monawarah	2.20	1.43	3.63	9.4
4	Al-Qaseem	2.11	1.34	3.45	2.2
5	Eastern region	13.20	4.73	17.93	3.9
6	Aseer region	2.79	1.89	4.68	8.4
7	Tabouk region	1.04	0.70	1.70	4.4
8	Ha'il region	0.90	0.65	1.55	5.0
9	Northern Borders	0.75	0.41	1.17	4.1
10	Jazan region	1.34	1.04	2.38	10.5
11	Najran region	0.95	0.51	1.47	6.3
12	Al-Baha region	0.61	0.41	1.02	12.5
13	Al-Jouf region	0.77	0.42	1.19	14.8
14	Undefined	0.04	0.02	0.06	

Source: General Authority for Statistics https://www.stats.gov.sa/en/823. [Accessed on 16/06/2020].
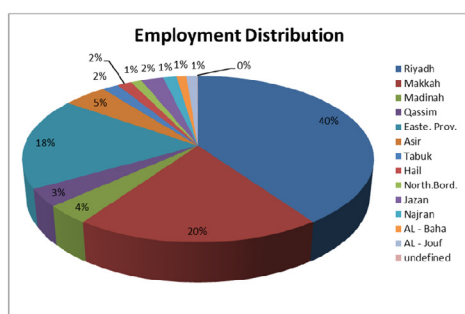
(a) Regional employment distribution in percentage

(b) Electrical energy consumption by sector for 2018
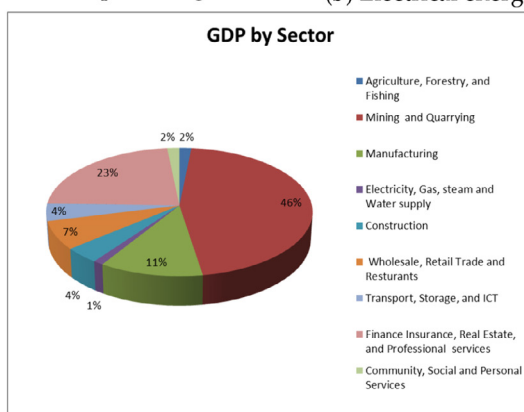
(c) Sectoral GDP contributions in percentage

Fig. 1. Employment distribution, energy consumption and GDP by sectors.

Table 2
Electrical energy consumption by sector for 2018.

S. No.	Sector	Consumption (Gw/H)	Percentage (%)
1.	Residential	130,428	43.60
2	Commercial	46,849	15.70
3	Government	43,909	14.70
4	Industrial	58,177	19.45
5	Others	19,824	6.63
	Total	299,188	100

Source: ECRA (2019).

mencement year of the analysis (Liuzzi et al., 2020). According to GAStat (2019), SA has nine sectors contributing to her economy (Table 3, Fig. 1c).

3.4. Greenhouse gas emissions

The value of CO_2 per person emission in KSA was approximated to be 18.56 tons, which led her to become the 15th top emitter during 2009 (Amran et al., 2020). KSA's current emissions are 517,079,407 tonnes of CO_2 equivalent and estimated to be 1.12 to 1.19 $GtCO_2e$ by the year 2030 (Transparency, 2018). The country's per capita CO_2 emissions in metric tons from 1960 to 2017 are depicted in Fig. 2. The country needs to emphasize the RES, such as wind, solar, geothermal energy, biomass, water, and ICT. The RES can be renewed continuously and naturally to minimize the high CO_2 emission level and invariably decrease electricity generation costs. They can replace coal, oil, and natural gas, which causes environmental safety. Carbon emission issues are addressed in several studies (Jemai et al., 2020; Yadav et al., 2021).

Table 3
Sectoral contribution to the identified goals.

S. No.	Economic sector	GDP at current price (2019) SR Millions	Electricity Consumption(MW)	Number of Employment('000)
1	Agriculture Forestry & Fishing	66,411	(*)	85,240
2	Mining & Quarrying	1,909,047	14613989	184,527
3	Manufacturing	476,947	78211969.18	824,735
4	Electricity, Gas, Steam & AC Supply, Water Supply, Sewage, Waste mgt, and Remediation Activities	47,174	862866.638	108,001
5	Construction	163,655	(†)	2,252,259
6	Wholesale & Retail Trade, Repair of Motor Vehicles & Motorcycles, Restaurants & Hotels	298,009	2036559.72	2,341,121
7	Transport, Storage, Information and Communication	182,071	(‡)	313,479
8	Finance Insurance, Real Estate, Professional and Administrative Services	952,222	(☆)	1,316,408
9	Community, Social & Personal Services	67,626	2146228.645	959,746

Source: GAStat (2019). (∗, †, ‡, ☆) = Electricity consumption for economic sector 1, 5, 7, & 8 is **201,316,387 MW.**
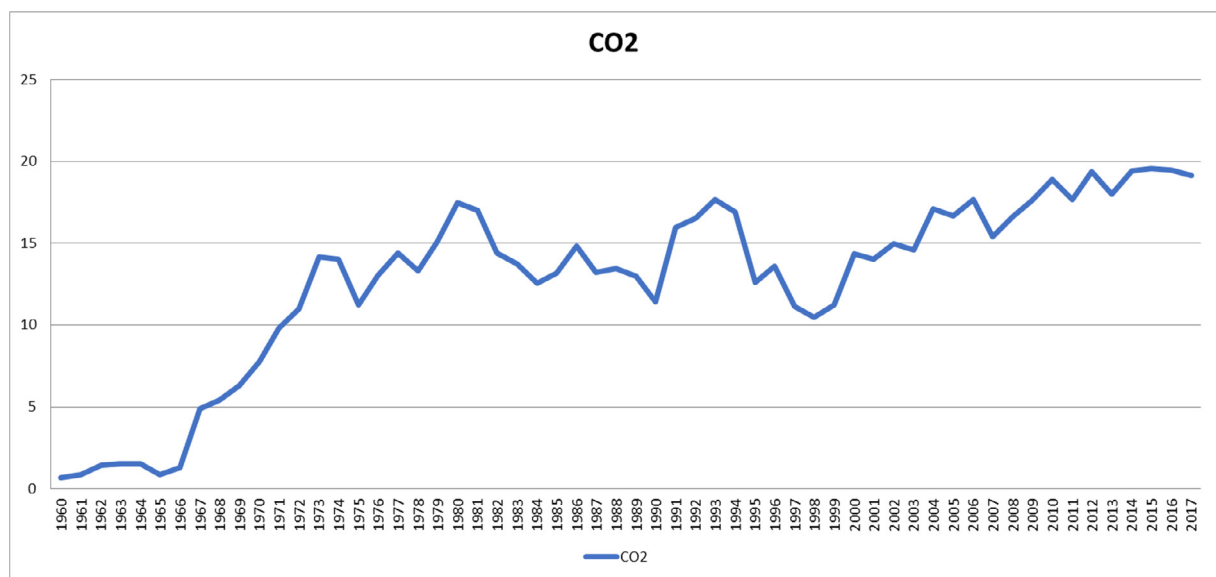

Fig. 2. CO_2 emissions (metric tons per capita) from 1960–2017.

4. Sustainable development goals

The United Nation's (UN) general assembly in September 2015, came up with an agenda for 2030 known as SDGs. The agenda comprises 17 goals, 169 targets, and 244 indicators. According to Modibbo et al., 2021, the goals are: "end poverty in all its forms everywhere; end hunger, achieve food security and adequate nutrition for all and promote sustainable agriculture; attain healthy life for all at all ages; provide equitable and inclusive quality education and life-long learning opportunities for all; achieving gender equality, empower women and girls everywhere; secure water and sanitation for all for a sustainable world; ensure access to affordable, sustainable and reliable modern energy services for all; promote robust, inclusive and sustainable economic growth and decent work for all; promote sustainable industrialization; reduce inequality within and among countries; build inclusive, safe and sustainable cities and human settlements; promote sustainable consumption and production patterns; promote actions at all levels to address climate change; attain conservation and sustainable use of marine resources, oceans and seas; protect and restore terrestrial ecosystems and halt all biodiversity loss; achieve peaceful and inclusive societies, rule of law, competent and capable institutions; and strengthen and enhance the means of implementation and global partnership for sustainable development."

5. SDGs model formulation

This section formulates the multi-objective problem relating to KSA's SDGs as a general model and optimizes them accordingly.

5.1. GDP related goal

These criteria measure the economic output of every sector in a given nation globally. In a particular economic sector *j*, a per capita gross domestic product is defined as a ratio of its GDP output (expressed in millions SR) by total employees in that sector (X_j^e) expressed in thousands during the commencement year of the analysis. According to GAStat (2019), KSA has nine sectors contributing to her economy (Table 3, Fig. 1c). The GDP related goal can be expressed as goal F_1 given by Eq. (1)

$$F_1 = \sum_{j=1}^{9} \left(\frac{GDP}{X^e}\right)_j, \tag{1}$$

The goal is that at the end of the vision year, the economic output should not be anything lesser than the estimated value given in Table 4, it serves as the constraint of the model.

Table 4
Goals current values and estimate for the year 2030.

S. No.	Goals	Current Value	Estimated value in the year 2030	Annual growth rate (%)
1.	Economic growth (GDP billion USD)	779.289[a]	800[b]	2.43
2	Electricity consumption	299,188 GWh[c]	442 TWh[d]	7.6[d]
3	Number of employment	3,170,272[e]	9,170,272[b]	88
4	Greenhouse gas emissions (GHGs)	517,079,407 tons	1.12 to 1.19 GtCO_2e[f]	4.94
5	Population	34,218,169[e]	39,322,336[e]	1.59

Source: [a]TradingEconomics (2019); [b]Institute (2015); [c] ECRA (2019); [d]Al and Csala (2019); [e]GAStat (2019); [f]Transparency (2018).

5.2. Electricity consumption goal

Similarly, the per capita electricity consumption (ECC) expressed in Mega Watt (goal F_2) for the nine contributing sectors can be computed similarly to model 1 as

$$F_2 = \sum_{j=1}^{9} \left(\frac{ECC}{X^e}\right)_j, \tag{2}$$

Here, the constraint of model 2 is to realise the estimated values of Table 4 by the year 2030.

5.3. Employment goal

For development enhancement, all economic sectors must ensure adequate required personnel for optimal running of the desired output sector's functionalities. The model for KSA is given as

$$F_3 = \sum_{j=1}^{9} X_j^e \tag{3}$$

The current number of employment (goal F_3) expressed in thousands across the nine economic sectors must be preserved and should not exceed the targeted value by the year 2030 (i.e. the constraint).

5.4. GHGs goals

The per capita GHG emissions (goal F_4) is expressed in tonnes of carbon dioxide equivalent per capita CO_2e, can be formulated as a ratio of CO_2e for sector j, expressed in thousands of tonnes by total employees in that sector in thousands (X_j^e). For the nine economic sectors of SA, the model can be expressed as

$$F_4 = \sum_{j=1}^{9} \left(\frac{GHGs}{X^e}\right)_j, \tag{4}$$

Similarly, goal F_4 is constrained to be optimize to reach at lease the estimated values (Table 4) by the year 2030.

The complete model formulation for Saudi Arabia, SDGs vision 2030 are summarized in Eq. (5), and can be optimized accordingly alongside their constraints.

$$F_1 = \sum_{j=1}^{9} \left(\frac{GDP}{X^e}\right)_j x_j, \ F_2 = \sum_{j=1}^{9} \left(\frac{ECC}{X^e}\right)_j x_j, \ F_3 = \sum_{j=1}^{9} X_j^e, \ F_4 = \sum_{j=1}^{9} \left(\frac{GHGs}{X^e}\right)_j x_j,$$

$$subject\ to :$$

$$\sum_{j=1}^{9} (GDP)_j X_j^e \geqslant (GDP)_g, \ \sum_{j=1}^{9} (ECC)_j X_j^e \geqslant (ECC)_g, \ \sum_{j=1}^{9} (X_j^e) \leqslant e_g,$$

$$\sum_{j=1}^{9} (GHGs)_j X_j^e \geqslant (GHGs)_g, \quad e_j \leqslant X_j^e \leqslant e_{g_j} \ \forall j = 1, 2, \ldots, 9,$$

$$\tag{5}$$

where constraint 1 places restrictions on the GDP goal. Constraint 2 places restrictions on the electricity consumption goal. Constraint 3 impose restrictions on the entire current number of workforce. Constraint 4 places restrictions on the GHGs emission goal. Constraint 5 impose restrictions on the goal of employment. e_g - the employment goal for vision 2030. $(GDP)_g$ - the gross domestic product goal for vision 2030. $(ECC)_g$ - the electricity consumption goal for vision 2030. $(GHGs)_g$ - the GHGs emission goal for vision 2030. e_{g_j} - the employment goal in j^{th} sector at the annual growth rate.

6. Methodology

This section discussed the methodologies used in this study.

6.1. Fuzzy goal programming (FGP)

Fuzzy goal programming is applied to the concept of fuzzy set theory. Fuzzy sets describe the imprecise goals of a DM. Fuzziness can be associated with an objective function or constraints. The degree (level of inclusion) of its memberships lies within a range of zero and one. The FGP concept in which both objectives and constraints are considered fuzzy was initially proposed by Zimmermann (1978). It is used widely for the uncertain condition (Sarkar et al., 2020; Tayyab and Sarkar, 2021). Mathematically, FGP is given as

$$Find\ a\ vector\ X = [x_1, x_2, \ldots, x_n]^T,$$
$$such\ that$$
$$F_k(X)(\succeq, \simeq, \preceq)\, g_k, k = 1, 2, 3, \ldots, K. \tag{6}$$
$$AX \leqslant b_i, i = 1, 2, \ldots, m,$$
$$X \geqslant 0,$$

where X is the vector of n decision variables, g_k is the vector of K goals, b_i is the vector of m available resources, and A is the technological coefficient. Symbols $\succeq$ is for fuzzy-max type, $\simeq$ for fuzzy-equal, and $\preceq$ for fuzzy-min type. The kth fuzzy objective and aspiration is denoted by F_k and g_k, respectively.

Eq. (7) shows the linear membership function for fuzzy-max goals type as follows

$$\mu_{F_k^{max}(X)} = \begin{cases} 1, & if\ F_k(X) \geqslant g_k, \\ \frac{F_k(X) - L_k}{g_k - L_k}, & if\ L_k \leqslant F_k(X) \leqslant g_k, \\ 0, & if\ F_k(X) \leqslant L_k. \end{cases} \tag{7}$$

The membership function for fuzzy-min goals type is given in Eq. (8) as

$$\mu_{F_k^{min}(X)} = \begin{cases} 1, & if\ F_k(X) \leqslant g_k, \\ \frac{U_k - F_k(X)}{U_k - g_k}, & if\ g_k \leqslant F_k(X) \leqslant U_k, \\ 0, & if\ F_k(X) \geqslant U_k. \end{cases} \tag{8}$$

The membership function for the fuzzy-equal goal type is given by Eq. (9) as

$$\mu_{F_k}(X) = \begin{cases} 0, & if\ F_k(X) \leqslant L_k, \\ \frac{F_k(X)-L_k}{g_k-L_k}, & if\ L_k \leqslant F_k(X) \leqslant g_k, \\ \frac{U_k-F_k(X)}{U_k-g_k}, & if\ g_k \leqslant F_k(X) \leqslant U_k, \\ 0, & if\ F_k(X) \geqslant U_k, \end{cases} \tag{9}$$

where U_k and L_k are the upper and lower limit of the aspiration levels g_k for k^{th} goal as given by the DM.

The fuzzy constraints membership function can be written as in Eq. (10)

$$\mu_{\tilde{g}_{F_k}}(X) = \begin{cases} 0, & if\ \tilde{g}_k(X) \leqslant b_i^L, \\ \frac{\tilde{g}_k(X)-b_i^L}{b_i-b_i^L}, & if\ b_i^L \leqslant \tilde{g}_k(X) \leqslant b_i, \\ \frac{b_i^U-\tilde{g}_k(X)}{b_i^U-b_i}, & if\ b_i \leqslant \tilde{g}_k(X) \leqslant b_i^U, \\ 0, & if\ \tilde{g}_k(X) \geqslant b_i^U, \end{cases} \tag{10}$$

where b_i^U and b_i^L are the upper and lower boundary limit of the equality constrain b_i for i^{th} constraint, and $\tilde{g}_k(X)$ is the kth fuzzy aspiration level given by Eq. (11).

$$\begin{cases} \tilde{g}_k(X) = \sum_{i=1}^{m} a_{ij}x_j(\succeq, \simeq, \preceq)\,b_i, \\ x_j \geqslant 0, j = 1, 2, \ldots, n. \end{cases} \tag{11}$$

6.2. Weighted fuzzy goal programming

The weighted fuzzy goal programming (WFGP) is useful in comparing two or more values of an objective function by the DM (Modibbo et al., 2021). The ultimate goal of the DM is to prioritize and solve conflicting goals simultaneously. The resulting solution must satisfy its aspirational level and is known as the ideal or Pareto solution. A weight w_i is assigning to all prioritized goals where a higher value predominantly goes with a high priority goal. However, the total sum of all w_i must equal to 1. There exist different weighting methods; they measure the deviations of the objectives relatively from there targeted goals to adjust its membership function. The WFGP with k fuzzy goals is as follows:

$$Maximize \sum_{k=1}^{K} \mu_k w_i$$

$$subject\ to:$$
$$\begin{aligned} \mu_k &\leqslant \frac{F_k(X)-L_k}{g_k-L_k}, & if\ L_k \leqslant F_k(X) \leqslant g_k, \\ \mu_k &\leqslant \frac{U_k-F_k(X)}{U_k-g_k}, & if\ g_k \leqslant F_k(X) \leqslant U_k, \\ \mu_k &\leqslant \frac{\tilde{g}_k(X)-b_i^L}{b_i-b_i^L}, & if\ b_i^L \leqslant \tilde{g}_k(X) \leqslant b_i, \\ \mu_k &\leqslant \frac{b_i^U-\tilde{g}_k(X)}{b_i^U-b_i}, & if\ b_i \leqslant \tilde{g}_k(X) \leqslant b_i^U, \\ x_j &\geqslant 0, & j = 1, 2, \ldots, n, \\ \mu_k &\geqslant 0, & \forall k, \end{aligned} \tag{12}$$

where w_k is the weight relatively assigned to each objective, and $\sum_{k=1}^{K} w_k = 1$. The weights to the objective function can obtain using the concept of analytic hierarchy process. The next subsection presents the approach.

6.3. Analytic hierarchy process

Analytic hierarchy process (AHP) is a well-known subjective technique for weight determination in multi-objective decision problems. It is useful in ranking a predetermined set of finite alternatives in the multi-criteria analysis (Modibbo et al., 2019, 2021).

The method was initially proposed by Saaty (1980), and applied in many domain of study. It is based on ratio scale that judgment are expressed as relative value of two entities. It help DM to focus better on some specific criteria or sub-criteria while allocating weights. The step wise procedure for the AHP is as follows:

Step 1. Construct the pairwise comparison $n \times n$ matrix with the help of scale of relative importance (Table 5) of alternatives/goals versus criteria/attributes/goals in light of Eq. (13).Table 6

$$A = \begin{bmatrix} 1 & a_{12} & \cdots & a_{1n} \\ 1/a_{21} & 1 & \cdots & a_{2n} \\ \cdots & \cdots & \cdots & \cdots \\ 1/a_{n1} & 1/a_{n2} & \cdots & 1 \end{bmatrix} \tag{13}$$

where $a_{ij} = 1/a_{ji}$, $a_{ij} > 0$.

Step 2. Normalize the pairwise comparison matrix in Step 1 using row geometric mean method (RGMM) and obtain the weights (w_j) as

$$w_j = \frac{\left[\prod_{j=1}^{i}\right]^{1/i}}{\sum_{i=1}^{n}\left[\prod_{j=1}^{i}\right]^{1/i}} \tag{14}$$

Step 3. Evaluate the consistency of the pairwise matrix in step 1 using consistency ration (CR) and consistency index (CI) using Eq. (15) suggested by Saaty (1980).

$$\begin{cases} CI = \frac{(\lambda_{max}-n)}{(n-1)} \\ \lambda_{max} = \sum_{j=1}^{n} \frac{(A \cdot v)_j}{(n \cdot v_j)} \\ CR = \frac{CI}{RI} \end{cases} \tag{15}$$

where A represent the pairwise matrix, v the matrix eigenvector, λ_{max} is the highes eigenvalue of the matrix, and RI is the Saaty randomly generated index from simulation for different size of n, and is given in Table.

Step 4. Finally, decide whether the matrix is reasonably consistent and acceptable or otherwise based on the value of CR. The acceptance value of the CR varies by the size of the matrix. For a 3×3 matrix, it is 0.05, and for a 4×4 matrix, it is 0.08, and for matrix of $n > 5$, it is 0.1 (Shameem et al., 2020).

The three goals of this study are the GDP, ECC, and X^e. Let their relative importance be given in matrix **A** in light of Eq. (13)

$$\mathbf{A} = \begin{matrix} GDP \\ ECC \\ X^e \end{matrix} \begin{pmatrix} GDP & 1 & 2 & 3 \\ ECC & 1/2 & 1 & 2 \\ X^e & 1/3 & 1/2 & 1 \end{pmatrix}$$

Table 5
Saaty fundamental scale.

Importance intensity	Defination
1	Equal importance
3	Moderate importance
5	Strong importance
7	Very importance
9	Extreme importance
2,4,6,8	intermediate values

Source: Saaty (1980).

Table 6
Consistency index for randomly generated pairwise matrix.

n	1	2	3	4	5	6	7	8	9	10
RI	0	0	0.58	0.9	1.12	1.24	1.32	1.41	1.45	1.45

Source: Saaty (1980).

Normalizing matrix **A** according to Step 2 of the AHP procedures using excel spread sheet, weights are 0.5390, 0.2973, and 0.1638 for GDP, ECC, and X^e, respectively. Further analysis reveals that the matrix is consistent with CR of 0.01 which is less than 0.05 for 3×3 matrix. Since the CR is less than the specified value, it can be concluded that the evaluation within the pairwise matrix is acceptable and AHP can be use in making the decision.

7. Result analysis and discussion

This section analyzes the model and discusses the result obtained and its implication to attaintment of KSA vision 2030 in light of SDGs.

The information in Table 4 and 3 use for the numerical results of Eq. (5) of Section 5 for the KSA. However, due to lack of data on the sectoral contribution for GHGs emissions, goal F_4 is not considered in the numerical solution. Thus, using LINGO optimization package version 16 (Guide, 2016), the individual optimal solution of formulated model obtained as **F_1 = 352168028**, **F_2 = 295084839**, and **F_3 = 4158457**, respectively. The procedure for the solving the multi-objective optimization problem is that, consider one objective under the same set of constraints and ignore others; solve and record the value of the objective function considered and that of variables in an n × n matrix. Use the record and interchange the objective functions and solve again using the same set of solutions obtained in the first instance until all objective values are exhausted and values obtained. Repeat the process using the sec-

Table 7
Solution to the weighted GP with maximum membership satisfaction.

Variable	Value	Reduced Cost
μ_1	0.4453146	0.000000
μ_2	0.6738684	0.000000
μ_3	0.7844499	0.000000
X_1	85240	0.000000
X_2	184527	0.000000
X_3	824735	0.000000
X_4	108001	0.000000
X_5	2252259	0.000000
X_6	230926600	0.000000
X_7	313479	0.000000
X_8	1316408	0.000000
X_9	959746	0.000000

Row	Slack or Surplus	Dual Price
1	0.5688585	1.000000
2	0.7131851E+14	0.000000
3	0.000000	0.000000
4	0.000000	0.000000
5	0.000000	0.000000
6	0.000000	0.1106465E−08
7	0.2899170E+09	0.000000
8	0.000000	−0.3164202E−07
9	0.000000	−0.4969487E−07
10	0.000000	0.000000
11	0.000000	−0.4589051E−06
12	0.000000	−0.3164202E−07
13	0.2285855E+09	0.000000
14	0.000000	−0.3164202E−07
15	0.000000	−0.3164202E−07
16	0.000000	0.000000

Source: Author's computation via Lingo System Inc (Guide, 2016).

ond goal until all exhausted. Then use the concept of fuzzy programming discussed in Section 6.1, and obtain the individual compromise solution. The results indicate that goals related to economic growth could be achieved by 47%, this could be attributed to the oil prices crisis in the world market due to the COVID-19 pandemic that resulted to the shutdown of business around the globe for nearly one year. Evident from Table 7, the goal of clean energy consumption is achievable by 67% in 2030. The goal related to employment is achievable by 78% based on the analysis; this is quite promising in attaining the vision 2030.

8. Conclusions

Achieving the sustainable development goals meant excelling and boosting the Kingdom of Saudi Arabia's economic growth. Economic growth was a desirable element for any nation's economy and is responsible for increasing energy consumption, contributing to CO_2 emission that affects the environment we live in. Adequate availability of electricity for satisfying high demands for both domestic and industrial usage is necessary. It is optimizing the standard of living by engaging more citizenry into jobs to guarantee future population expansion and ensuring environmental safety.

The study modelled the SDGs of Saudi Arabia mathematically and quantified its achievement by 2030 to the best of our knowledge. The analysis showed that only 47% GDP related goals, 67% in energy consumption related goals, and 78%, and job-related goals will be achieved by the year 2030. Despite the increment in electricity tariff by the kingdom in an attempt to benchmark the domestic energy price with international standards, the country needed to diversify its energy mix and invest more in renewable energy sources to meet the industrial and domestic energy demands. More talented and productive youths should be engaging in boosting all the economic contributing sectors' output to raise and stimulate government revenues and productivity.

Declaration of Competing Interest

The authors declare that they have no known competing financial interests or personal relationships that could have appeared to influence the work reported in this paper.

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